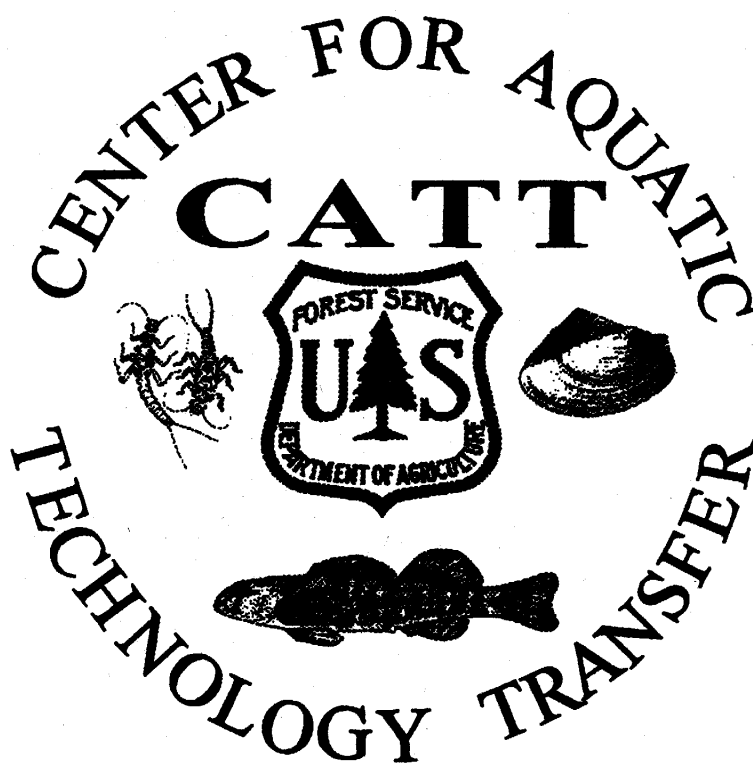


**Current Conditions of Habitat and Fish in Wonalancet Brook, White Mountain
National Forest, New Hampshire**



**United States Department of Agriculture Forest Service
Center for Aquatic Technology Transfer
Department of Fisheries and Wildlife Sciences
Virginia Tech, Blacksburg, VA 24061-0321**

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Introduction

Streams in the eastern United States that flow through old-growth forest are distinctly different from streams that flow through managed forest (Flebbe and Dolloff 1995). Past land-use practices have resulted in changes to streams that affect nutrient levels, water balance, sediments, vegetation and debris, water quality, and the distribution and abundance of aquatic organisms (Chamberlin et al. 1991). Where available, old-growth-forest streams can provide managers with valuable insight into the mechanics of naturally functioning systems which can be used as a template for stream-health assessments, stream habitat improvement, and monitoring.

One major difference between old-growth forest streams and other streams is the high abundance of instream large woody debris (LWD) in old-growth forest (Franklin et al. 1981; Silsbee and Larson 1983; Harmon et al. 1986; Bisson et al. 1987; Flebbe and Dolloff 1995). Large woody debris is associated with many of the physical, chemical, and biological processes that occur in streams (Dolloff 1994). Woody material dissipates energy and stores both organic and inorganic sediments (Harmon et al. 1986); serves as an energy and nutrient source and a site for nitrogen fixation (Triska et al. 1982); and influences the complexity, diversity, and distribution of habitats for aquatic fauna and thus biological productivity (Harmon et al. 1986; Dolloff 1994). Because LWD influences such a broad array of the ecological processes in streams, its distribution and abundance may be a useful surrogate measure for many of these processes and therefore a useful tool for evaluating conditions in streams on managed forest lands.

As in most of the continental United States, the long history of logging and land clearing in the White Mountain National Forest (WMNF), New Hampshire, has left very few forest stands that have not been disturbed by humans at least one time (Leak 1973). As a result, most of the WMNF streams are noticeably lacking LWD (Kathryn Staley, WMNF Forest Biologist, personal communication). One exception is a virgin stand of spruce-fir and northern hardwoods, known as the Bowl (Leak 1973). Wonalancet Brook, a small headwater stream which flows through the Bowl, provides a

unique opportunity to investigate natural stream processes, particularly LWD loadings, in the WMNF. The purpose of this study was to quantify stream habitat and fish abundance in Wonalancet Brook to be used as a baseline for assessing the relative condition and health of other similar sized streams on the WMNF.

Methods

A modified basinwide inventory technique (Staley 1995) was used to inventory stream habitat in 3.1 miles of Wonalancet Brook in July 1997 (Figure 1). The 3.1 mile study section was divided into four contiguous reaches based on channel type (Rosgen 1985), landmarks, and tributary confluences (Figure 1). Habitat measurements collected in each of the identified reaches included: channel type, habitat type (e.g. pool, riffle, etc.), habitat unit width (ft), maximum and average depth (0.1 ft), substrate composition (modified Wentworth scale), LWD, instream cover, bankfull width and depth, substrate embeddedness, riparian vegetation, and canopy cover (Appendix A).

Inventories of fish distribution and abundance were conducted only in reaches 2 and 3 (Figure 1). Underwater observations were made in systematically selected habitat units (20 pools and 11 riffles). Fish populations were censused by divers equipped with face mask and snorkel. Two divers carefully entered each selected habitat unit and recorded the species, numbers, and relative size (e.g. age 0+, 1+, and 2+) of all fish observed.

Multiple-pass removal (Zippen 1958) electrofishing (two backpack DC electrofishers) was used to sample fish in 10 pools and one riffle sampled by divers. This paired subset, selected systematically, was used to calibrate diver counts and obtain a more accurate estimate of fish abundance (Hankin and Reeves 1988) in Wonalancet Brook. All fish were identified, measured (mm-total length [TL]) and weighed (g) before being returned to their approximate location of capture.

Fish measurements were used to calculate relative weights (fish ≥ 130 mm TL) and length frequency distributions. Total fish abundance and density (number of fish per 100 ft²) was estimated for each habitat type for reaches 2 and 3.

Results

Habitat

The survey crew identified 62 pools (includes two glides) and 88 riffles (includes one waterfall) in the 3.1 mile study section of Wonalancet Brook. Visual estimates of stream surface area were paired with measured stream surface area for 60 pools and 28 riffles. Paired observations were highly correlated for pools ($r = 0.98$, $p < 0.001$) and riffles ($r = 0.94$, $p < 0.001$).

Total surface area was estimated to be 20,778 ft² (95% confidence interval ± 77 ft²) for pools and 243,364 ft² (95% confidence interval $\pm 4,552$ ft²) for riffles using correction factors (\bar{Q}) that ranged from 1.006 (pools) to 1.001 (riffles). This indicates that less than 8% of the total habitat area were pools (Figure 2). Pools represented about 11% of the total habitat area in Reach 2 but 8% or less of the total habitat in the remaining three reaches (range = 5 - 8%).

The mean maximum depth in pools and riffles in the study area were 2.6 ft and 2.0 ft, respectively, and a mean riffle crest depth of 0.7 ft (Figure 3). The mean average depth in pools was 1.5 ft and 0.9 ft for riffles.

In general, the dominant and subdominant substrata in the study section tended to be coarse (Figures 4 and 5). The most common (modal) substrata were boulder and large gravel in pools and cobble and boulder in riffles.

The study section contained about 281 pieces of LWD per mile with more than 46 pieces per mile of the largest size class (Figure 6). The larger pieces of wood tend to be the most stable, the most capable of forming instream habitat, and provide the best cover for fishes (Dolloff 1994). Although large pieces of wood were found throughout the study section, the greatest number of pieces were found in Reach 2 (73 per mile; Figure 7). The total amount of wood in the largest size class ranged from 21 to 69 pieces per mile for the remaining three reaches (Figure 7).

The dominant riparian vegetation, and thus the most available for LWD recruitment, was Northern Hardwoods: sugar maple (*Acer saccharinum*), red maple

(*Acer rubrum*), beech (*Fagus grandifolia*), and yellow birch (*Betula alleghaniensis*). The riparian area also contained eastern hemlock (*Tsuga canadensis*), and paper birch (*Betula papyrifera*) (Figure 8).

The dominant cover for fish in the study section was substrate (e.g. boulders), while the subdominant cover was water turbulence (Figure 9). Depth greater than 2.5 feet, woody material, and undercut banks were also available fish cover (Figure 9).

The mean bankfull width in the study section was 20.1 ft (range = 8 - 34 ft) (Figure 10). The mean bankfull depth ranged from 0.7 to 3.5 ft, with a mean of 1.6 ft (Figure 11). This suggests that channel entrenchment in Wonalancet Brook is shallow to medium.

Fish

Brook trout was the only species observed in reaches 2 and 3. Both adult and young-of-year (YOY) were observed throughout these reaches (Figure 12). No brook trout were observed in five additional pools snorkeled in the lower portion of Reach 4 and may indicate the upstream extent of this species (Figure 12).

Population estimates and 95% confidence intervals were calculated for both adult and YOY brook trout in pools. Population estimates were calculated for riffles but variance, and subsequently 95% confidence intervals, could not be calculated because only one of eleven snorkeled riffles was electrofished (paired samples = 1). Population estimates for adult brook trout were 309 (± 69) in pools and 1669 in riffles and those for YOY were 22 (± 42) in pools and 367 in riffles (Table 1).

Brook trout densities were calculated separately for pools (area = 12,972 ft²) and riffles (area = 117,937 ft²) and ranged from 0.2 / 100 ft² for YOY to 2.4 / 100 ft² for adults (Figure 13). Mean density for young-of-year brook trout was slightly higher in riffles than in pools, whereas the mean density for adults was highest in pools (Figure 13).

Analysis of length frequency indicates the brook trout population in the study section is comprised of at least three size classes (Figure 14). Fish lengths ranged from 30 to 47 mm in the first size class (n = 11) and 72 to 161 mm in the second (n = 63). The third size class was comprised of one 217mm brook trout (Figure 14).

Total lengths and weights for brook trout greater than 130 mm were used to calculate relative weight (W_r). The relative weight index allows interpopulational comparisons by making the standard weight-length regression species-specific rather than population specific (Murphy et al. 1991). The condition of brook trout in the study area were therefore compared with those in eight similar sized streams in Shenandoah National Park (SNP), VA. The analysis indicated brook trout in the study section were in moderate to poor condition relative to those in SNP (Figure 15).

Discussion

The trees available for LWD recruitment in Wonalancet Brook included a mixture of mature northern hardwoods and eastern hemlock. At present, little is known about the appropriate species or mixture of species to be managed for LWD although it may depend on site suitability, resistance to decay, and other riparian management objectives (Dolloff 1994).

Large woody debris was a common feature of the Wonalancet Brook stream channel. Because many factors affect LWD loading in streams (e.g. channel size, forest type, disturbance history; Sedell et al. 1988), one would expect high variability in the number and distribution of LWD among streams; even among those flowing through old-growth forest. We presently lack the information on the variation of LWD loadings in streams flowing through old-growth forest in the northeastern United States. Nevertheless the LWD loading observed in Wonalancet Brook (~281 pieces per mile) was more similar to those observed in old-growth forest than in second-growth forest of the southern Appalachian Mountains. For example, Dolloff (1994) reported LWD loadings in the southern Appalachian Mountains that ranged from 64 to 104 pieces of LWD per mile in two streams flowing through second-growth forest and 360 to 416 pieces of LWD per mile in two streams flowing through old-growth forest. We suggest that Wonalancet Brook exhibits the high LWD complexity that is common to old-growth streams and therefore a useful baseline for approximating natural LWD loadings in the WMNF.

One important function of LWD in streams is its role in the formation of pool habitat (Dolloff 1994). Because of the high abundance of wood observed in Wonalancet Brook, we would expect a greater percentage of the total habitat to be pools than was observed. This may be due to the inventory protocol used in this study. Pools in Wonalancet Brook were defined as habitat units having a length greater than the wetted width, and/or a maximum depth greater 2.5 ft; a definition most commonly used to describe 'primary pools'. The smaller and shallower pools were included in the riffle habitat.

Stratifying by primary pools grossly underestimated the percentage of total pool area and may have resulted in the misrepresentation of brook trout distribution and abundance among habitat types. For example, about 41% of the riffles sampled had a maximum depth greater than 2.5 ft which indicates that there may be more suitable brook trout habitat in Wonalancet Brook than was represented by primary pools. About 84% of the estimated population for adults and about 94% of the estimated population for YOY in the study area were observed in riffles. Conversely, data collected by the USFS Southern Research Station (SRS) in the Appalachian Mountains of Virginia, Tennessee, North Carolina, South Carolina, and Georgia indicates that trout preferentially use pools over riffles. For these reasons, we recommend that the WMNF adopt habitat classification procedures used by the SRS for future habitat surveys.

We observed at least three distinct size classes of brook trout in Wonalancet Brook which indicates at least a three year lifespan. These data, however, should be interpreted with caution. Visual implant tag data collected in the Southern Appalachians on rainbow trout (*Oncorhynchus mykiss*) and brook trout revealed that individual trout live to age-VI with little growth observed after age-III (C.A. Dolloff, USFS-SRS Fisheries Scientist, personal communication). Studies of individual brook trout, over time, are needed to determine longevity and obtain a more accurate estimate of age structure in northeastern streams.

Finally, the relative weights of brook trout in Wonalancet Brook appear to be in the moderate to poor range when compared to their conspecifics further south. Milder

winter temperatures and a longer growing season in the south may partially explain the differences in relative weight observed between the two regions. Numerous other physical, chemical, and biological processes, however, affect fish growth. Because these processes and interactions are likely to vary among regions, we suggest relative weights, representative of the northeast, be calculated and used to compare the condition of brook trout among WMNF streams. Comparisons of brook trout relative weights by stream or watershed may provide insight into differences in productivity in streams flowing through old-growth and managed forest in the Northeast.

In conclusion, the data collected on Wonalancet Brook provided insight into the structural and functional characteristics of a stream flowing through an undisturbed forest in the northeastern United States. The long history of forest and river management in the Northeast has changed the appearance of streams flowing through forested watersheds so it is difficult for most people to realize that LWD in streams is a natural part of the biological and hydrological processes of streams and a crucial component of stream health. The high woody debris loadings observed in Wonalancet Brook demonstrates this link between aquatic streams and terrestrial environments.

We suggest that conditions in Wonalancet Brook, as well as other streams flowing through old-growth forest in the Northeast, be used as baselines for estimating natural woody debris loading in streams on the WMNF and a template for future stream habitat improvements or restorations. Direct additions of LWD (to address specific current conditions) and natural recovery of the riparian area (to address long-term goals) are two management practices that can be used for effective stream improvements. Widths of streamside management zones, in relation to the probability of LWD recruitment, should also be considered when developing management plans (Dolloff 1994). Management of LWD will be most effective when approached from a watershed scale based on multiple disciplines including fisheries, hydrology, silviculture, and engineering.

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Table 1. Population estimates for brook trout in Wonalancet Brook based on the basinwide survey.

Adult Brook Trout	Pools	Riffles
Avg. Number of Fish	3.95	14.64
Calibration Factor	2.06	2.78
Corrected Avg. Number of Fish	8.137	40.69
Number of Habitat Units	38	41
Corrected Population Estimate	309.21	1668.67
Calculated Variance	33.19	N/A
Calculated 95% Confidence Interval	69.47	N/A
Young of the Year Brook Trout	Pools	Riffles
Avg. Number of Fish	0.75	6.73
Calibration Factor	0.79	1.33
Corrected Avg. Number of Fish	0.59	8.95
Number of Habitat Units	38	41
Corrected Population Estimate	22.40	366.98
Calculated Variance	20.14	N/A
Calculated 95% Confidence Interval	42.15	N/A

White Mountain National Forest Wonalancet Brook

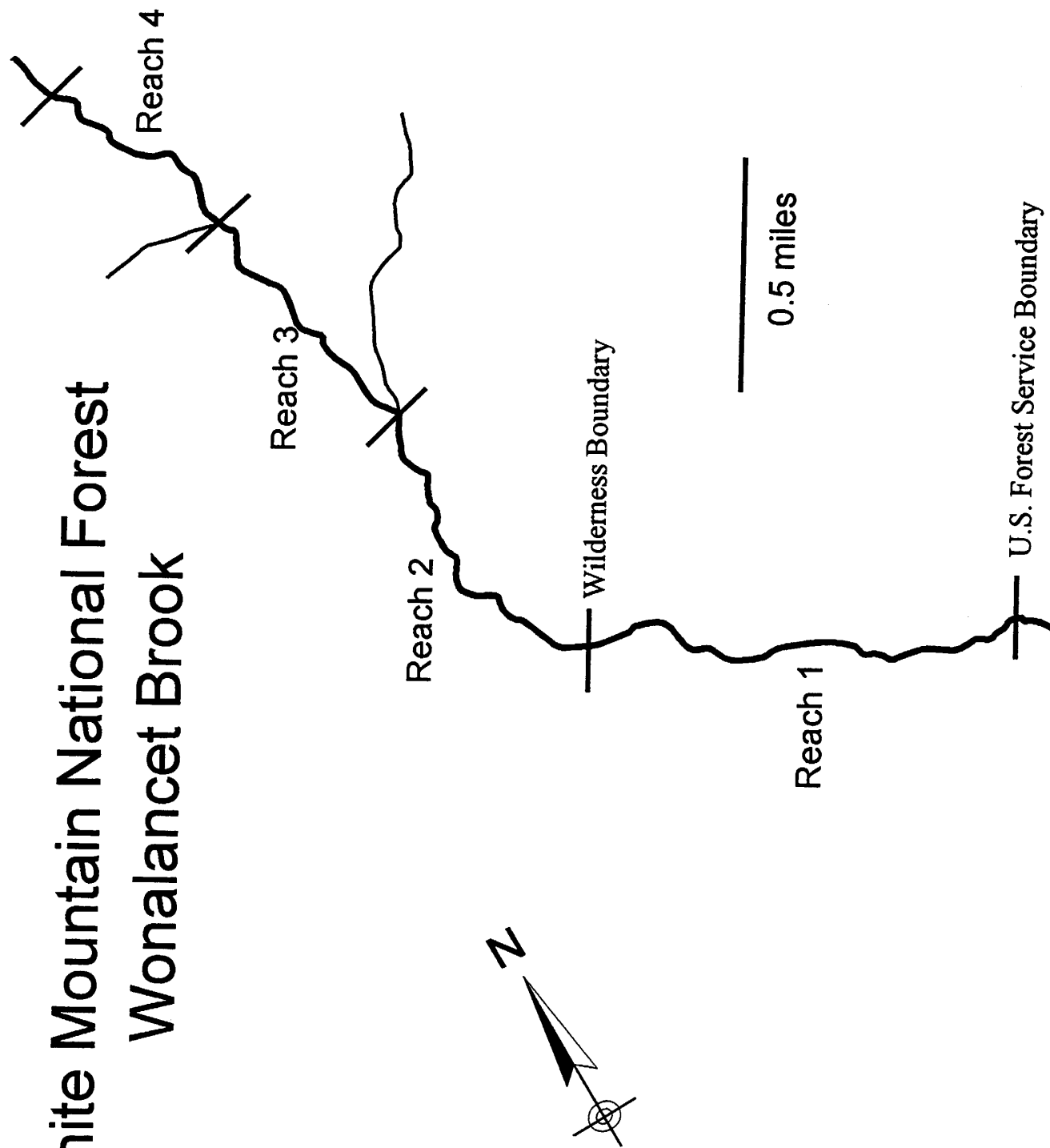


Figure 1. Wonalancet Brook, in the White Mountain National Forest . Lines indicate endpoints of the four study reaches.

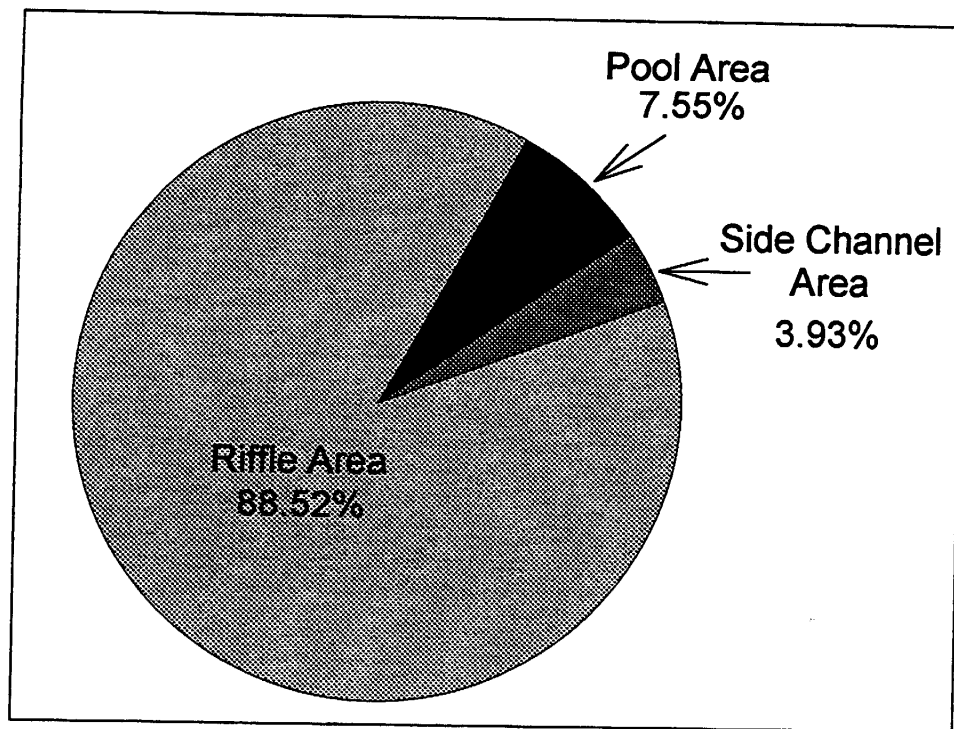


Figure 2. Percent of surface area comprised of each habitat type in Wonalancet Brook.

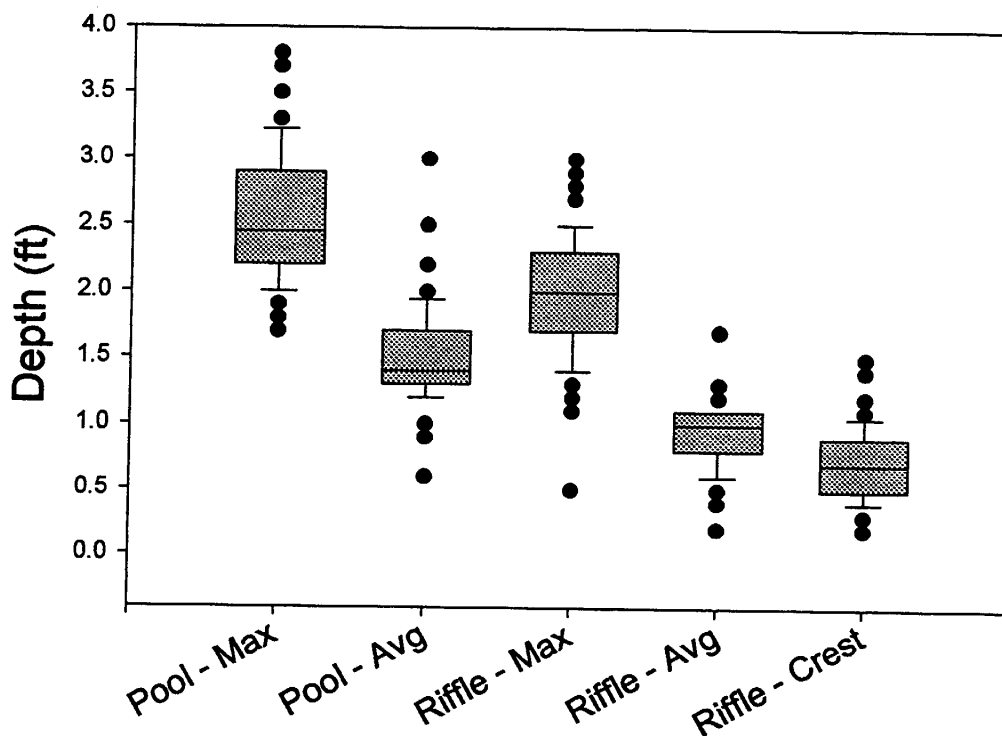


Figure 3. Box plots representing maximum and average depths for pools and riffles, and depth at riffle crest. The boxes enclose the middle 50% of the observations, the bar in the center of the boxes represent the median, and the capped lines extending above and below the boxes represent the 90% and 10% quantiles.

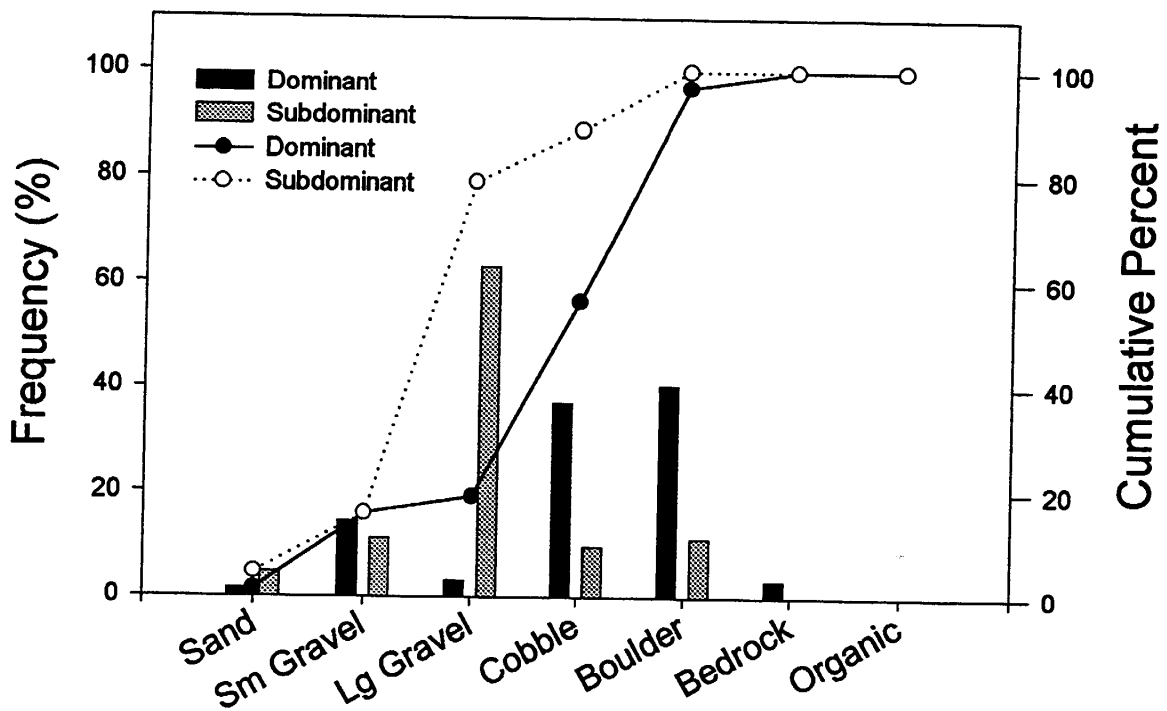


Figure 4. Dominant and subdominant substrate composition in pools of Wonalancet Brook. Bars represent frequency; dots and lines represent cumulative percent.

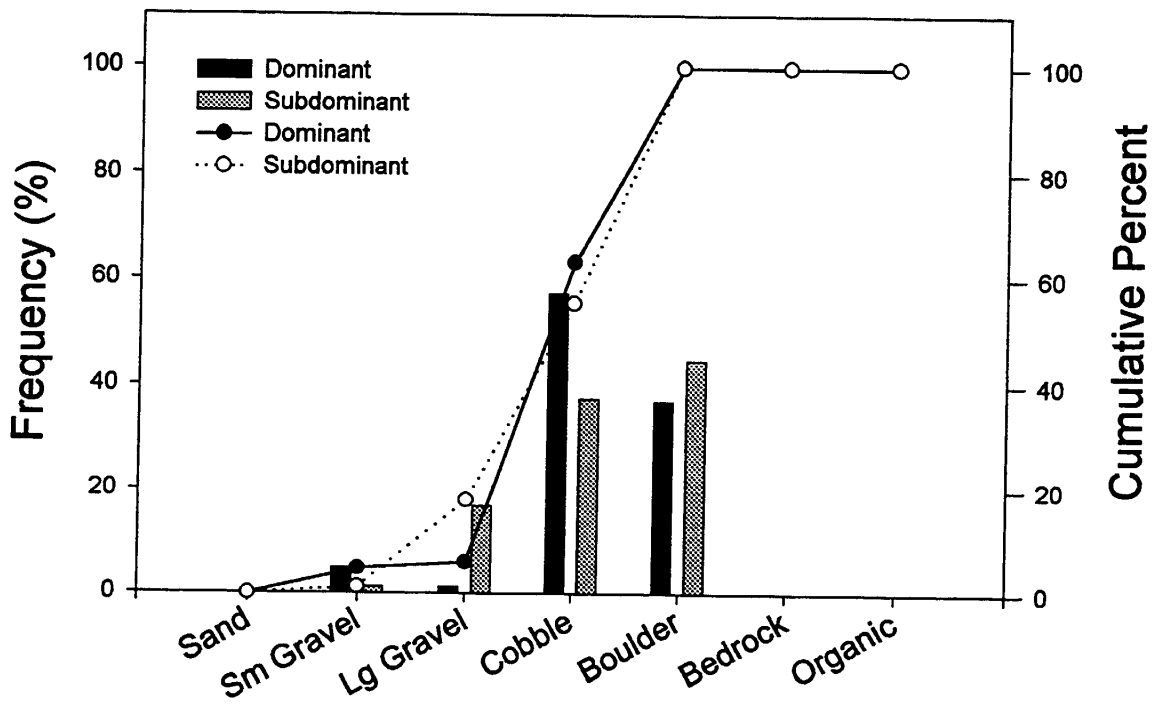


Figure 5. Dominant and subdominant substrate composition in riffles of Wonalancet Brook. Bars represent frequency; dots and lines represent cumulative percent.

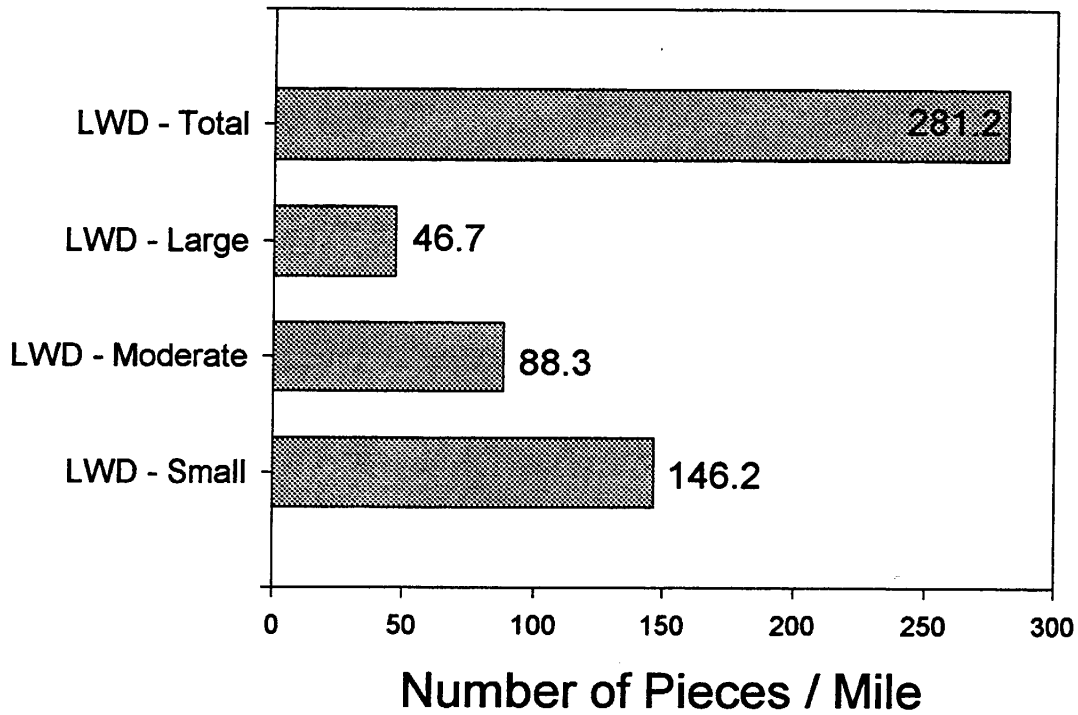


Figure 6. Pieces of large woody debris per mile in Wonalancet Brook.

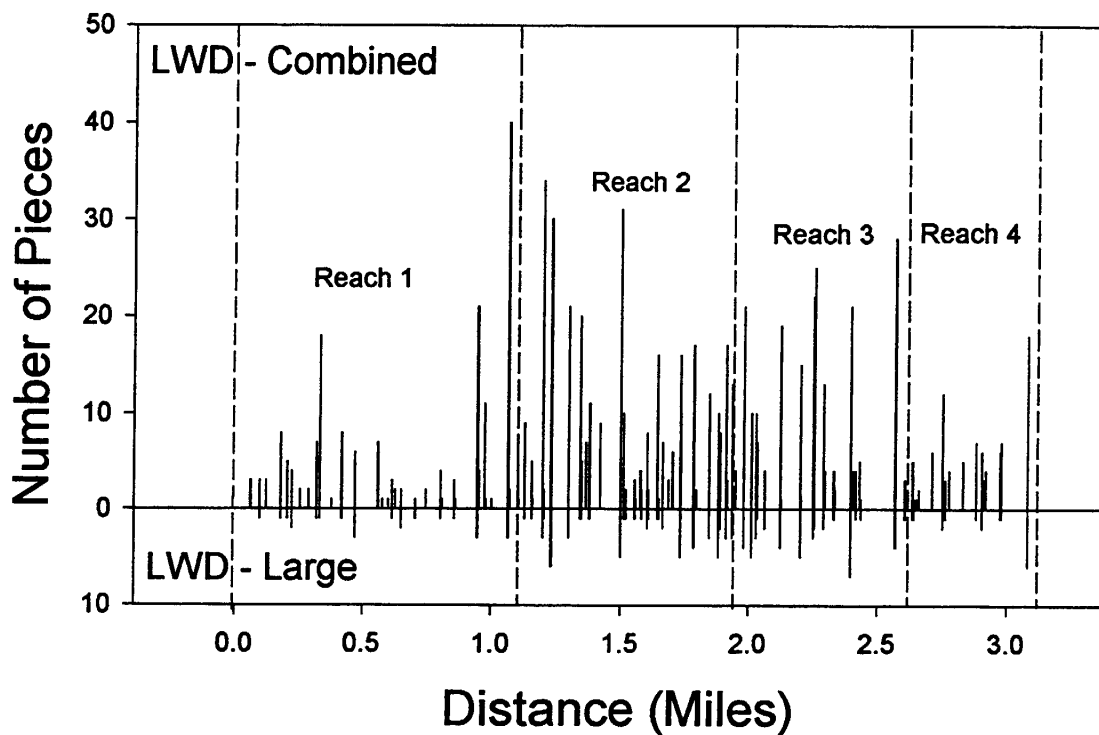


Figure 7. Distribution of large woody debris in Wonalancet Brook. Broken lines indicate endpoints of the four study reaches.

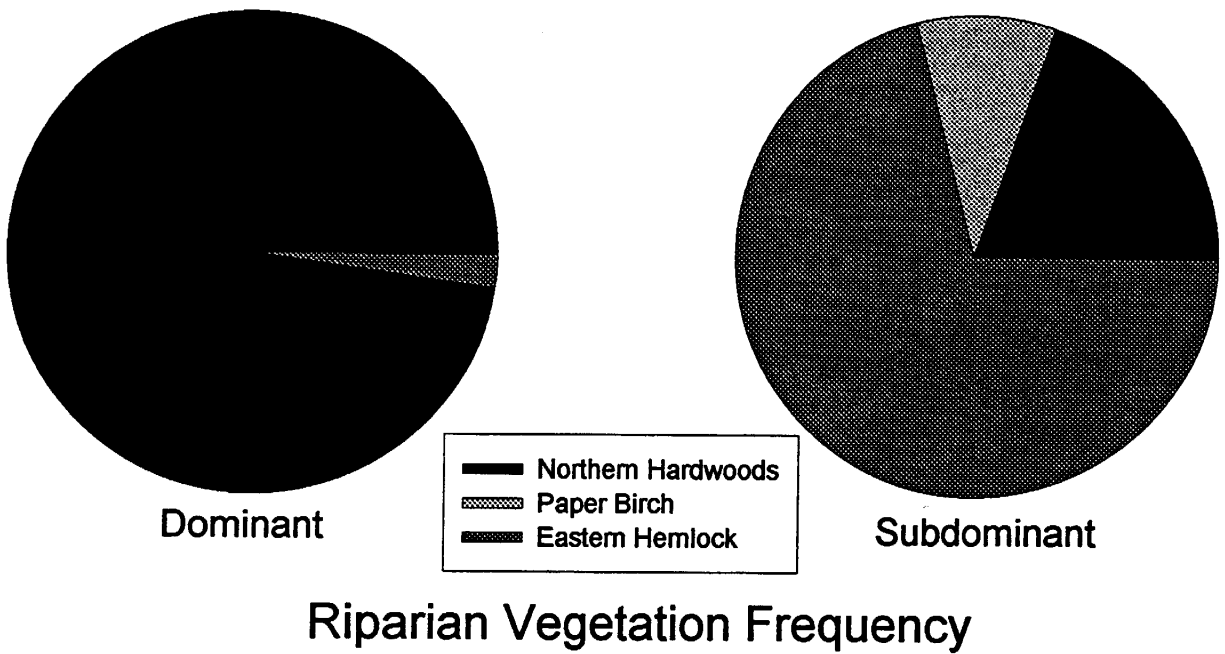


Figure 8. Percent of riparian vegetation in Wonalancet Brook.

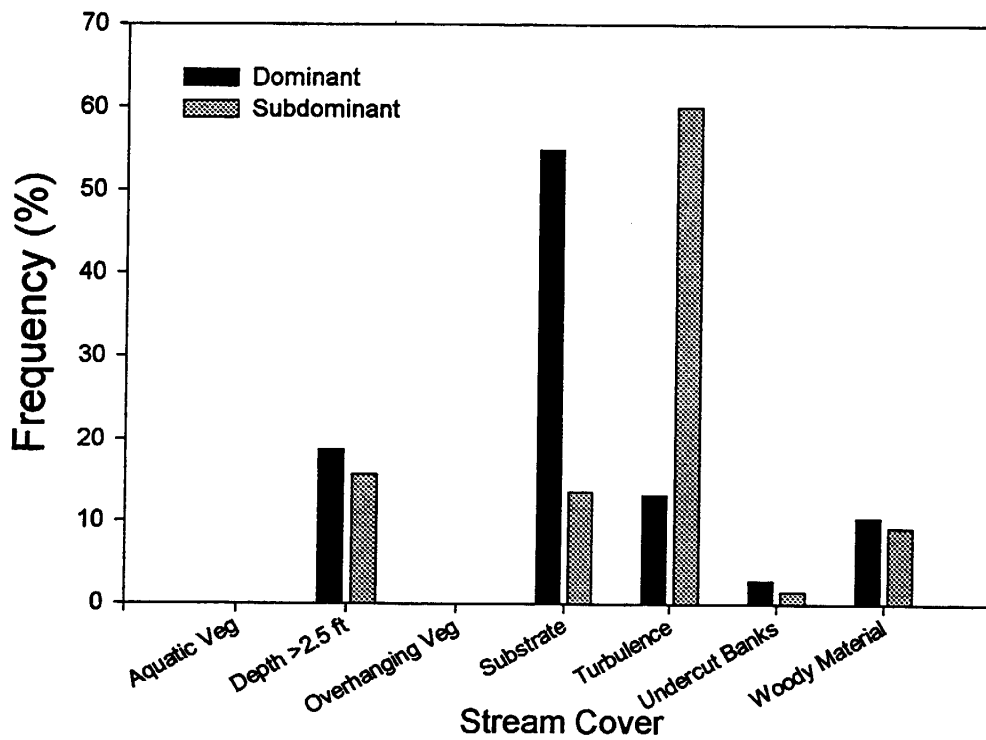


Figure 9. Dominant and subdominant stream cover in Wonalancet Brook.

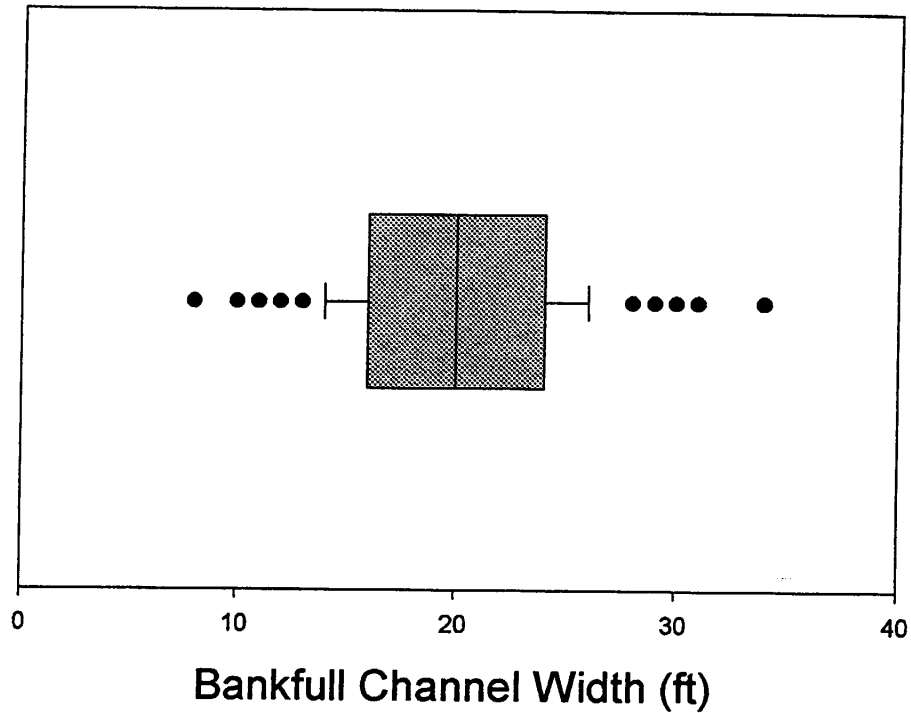


Figure 10. Box plot of bankfull width in Wonalancet Brook. The box encloses the middle 50% of the observations, the bar in the center of the box represents the median, and the capped lines extending above and below the box represent the 90% and 10% quantiles.

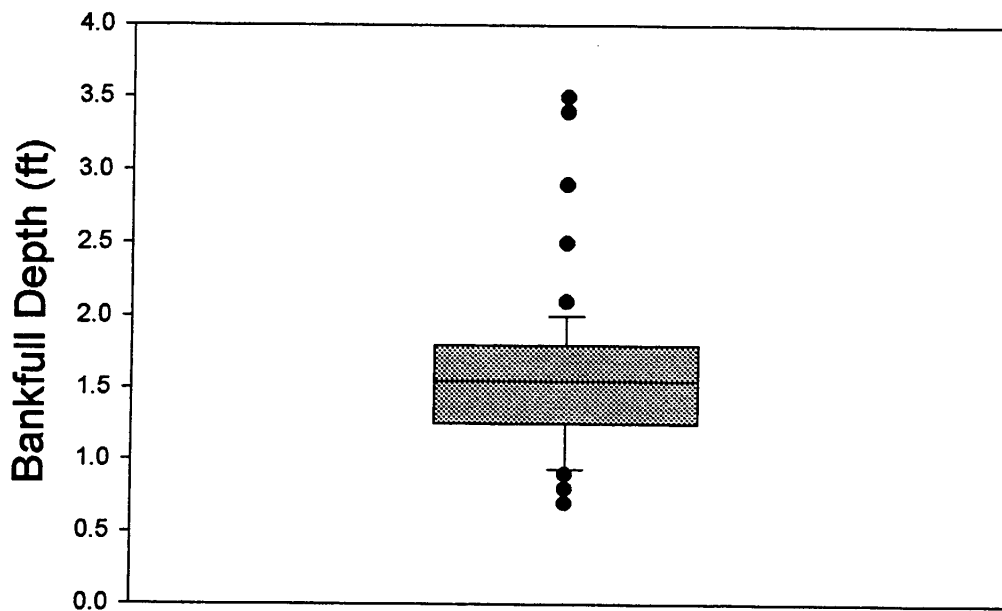


Figure 11. Box plot of bankfull depth in Wonalancet Brook. The box encloses the middle 50% of the observations, the bar in the center of the box represents the median, and the capped lines extending above and below the box represent the 90% and 10% quantiles.

Wonalancet Brook Brook Trout Distribution

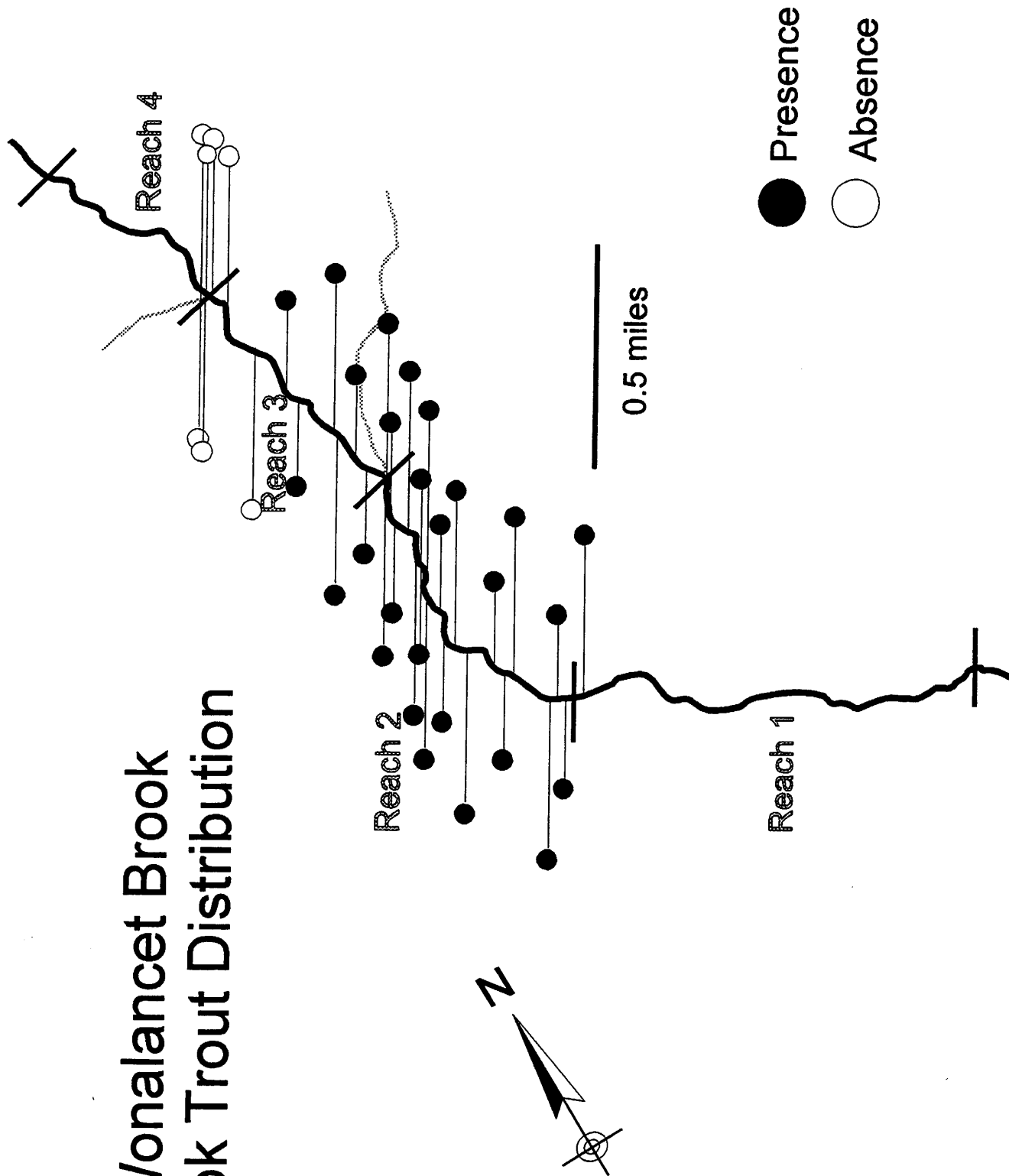


Figure 12. Distribution of brook trout in Wonalancet Brook, based on the basinwide survey of Reaches 2 and 3.

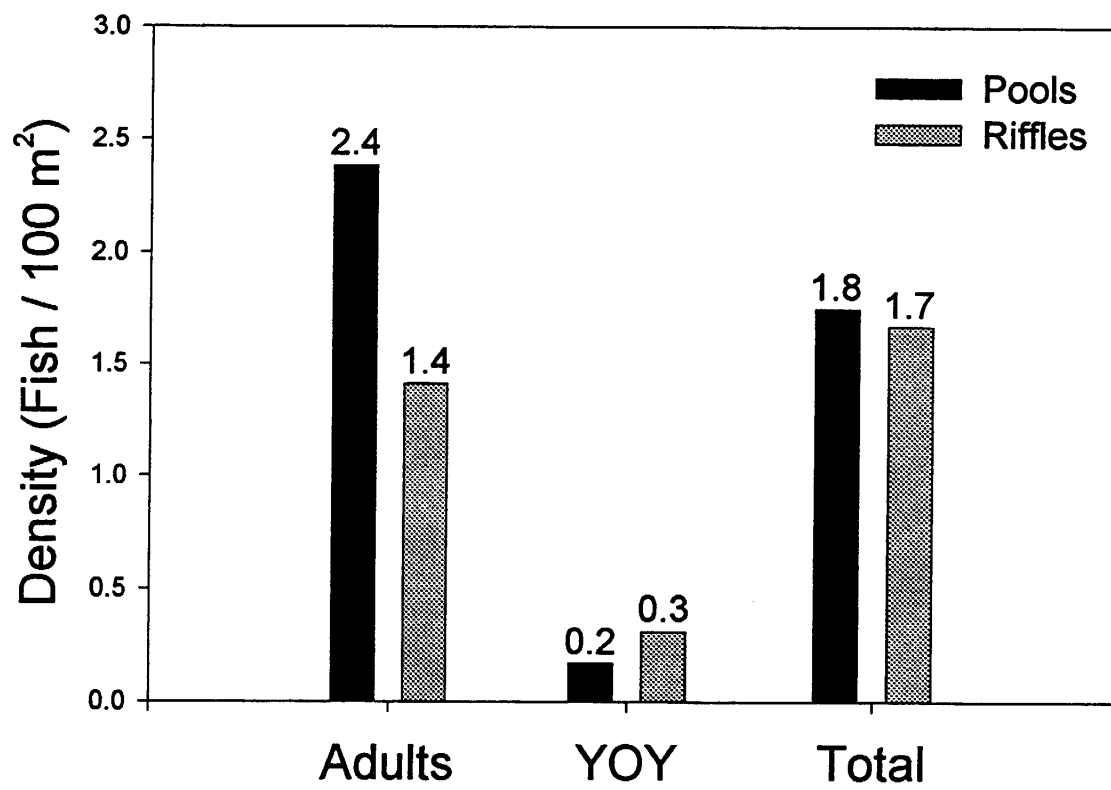


Figure 13. Densities of brook trout in Wonalancet Brook for adults, young-of-year, and adults-yoy (combined).

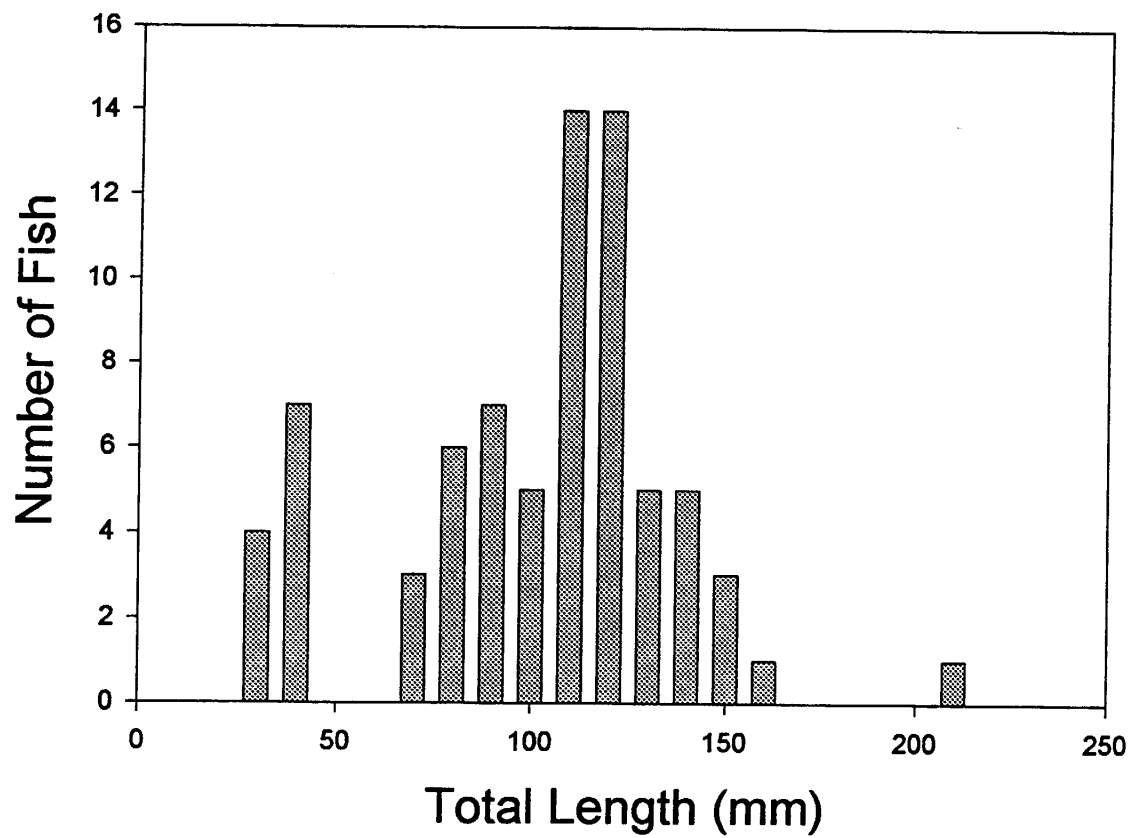


Figure 14. Length frequency of brook trout in Wonalancet Brook.

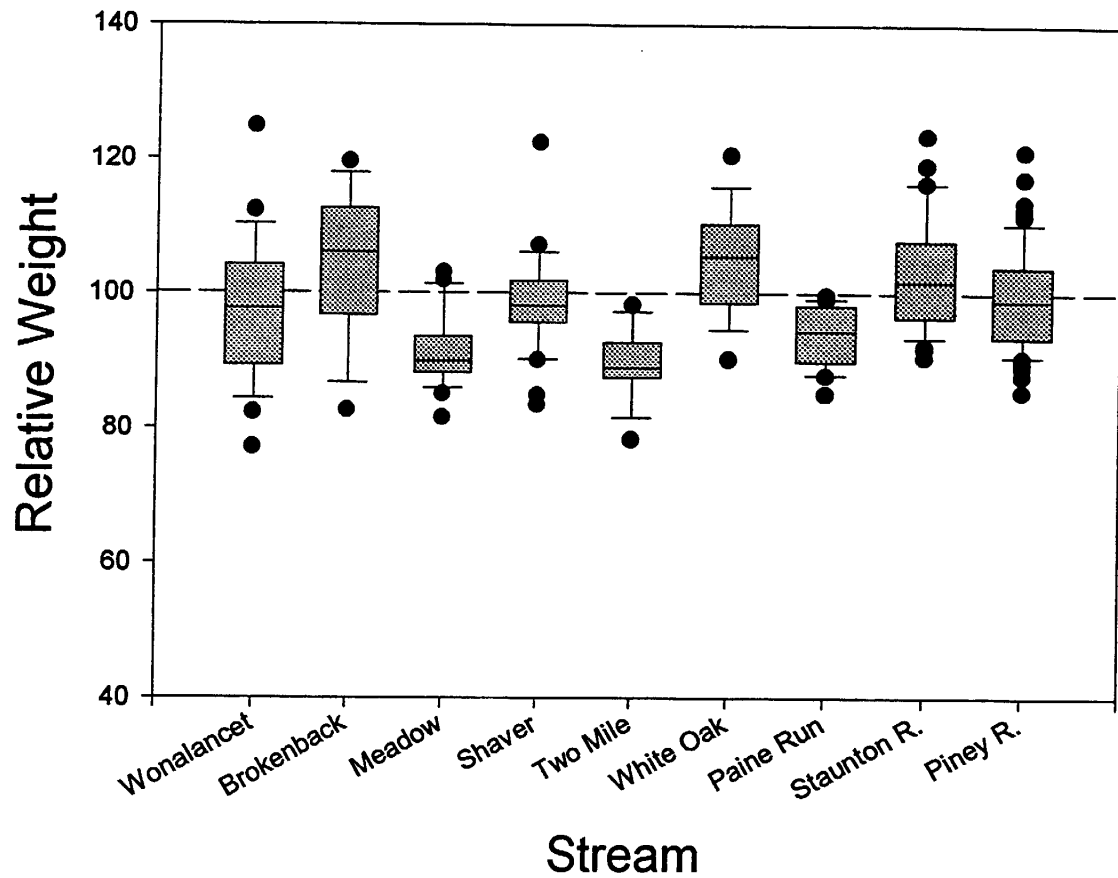


Figure 15. Box plots of relative weight for Wonalancet Brook and various streams from the Shenandoah National Park for comparison. The boxes enclose the middle 50% of the observations, the bar in the center of the boxes represent the median, and the capped lines extending above and below the boxes represent the 90% and 10% quantiles. The dashed line at a relative weight of 100 represents the benchmark for good condition.

Appendix A. Substrate composition, stream cover, large woody debris, and riparian vegetation parameters. DBH = diameter at breast height.

Substrate

SA = Fines/ Silts/ Sand	< .25 inch in diameter
G1 = Small Gravel	.25 to 3.0 inches
G2 = Large Gravel	3.1 to 6.0 inches
CO = Cobble	6.1 to 12.0 inches
BR = Bedrock	Large solid mass
OR = Organic	Wood and/ or herbaceous

Stream Cover

U = Undercut banks
S = Substrate
D = Depth (> 2.5 feet)
H = Overhanging vegetation (<10" above water)
W = Woody Material
T = Turbulence
A = Aquatic emergence vegetation

Large Woody Debris

Small: > 6 ft but < 15 ft in length; < 12 in. DBH
Moderate: > 15 ft and < bankfull width in length; < 12 in. DBH
Large: > bankfull width in length; > 12 in. DBH

Riparian Vegetation

NH = Northern Hardwoods (Sugar Maple, Red Maple, Beech, Yellow Birch)	
PB = Paper Birch	QA = Aspen
SF = Spruce/ Fir	OP = Oak/ Pine
EH = Eastern Hemlock	WL = Wildlife Openings (perm. managed)
WT = Wetland	RL = Rockledges, orchards, or "other"